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AIR-CORED IMPULSE BETATRONS,(U)
JAN 80 A I PAVLOVSKIY, G D KULESCHOV
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AIR-CORED IMPULSE BETATRONS

By

A. I. Pavlovskiy, G. D. Kuleschov

EDITED TRANSLATION

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

AIR-CORED IMPULSE BETATRONS

A. I. Pavlovskiy, G. D. Kuleschov

In 1955 work began on cyclic induction accelerators with air-cored electromagnets. After one and a half years, the first operating air-cored betatron projects were completed. Further development in this direction brought the advent of high-current betatrons in which high accelerating energy combines with great circulating currents [1].

One of the developed accelerator variants of this type is described below.

Electromagnet

In the development of air-cored electromagnets, main attention was given to achieving the necessary characteristics determining the intensity of the electron beam: to maximize as much as possible the aperture of the stability area and distribution of the magnetic field which provides sufficiently effective axial and radial beam focusing. Along with this, to achieve high values of acceleration energy it was necessary to construct electromagnets with high mechanical and electric strength.

An electromagnet which fullfils these requirements to a sufficient degree is shown in Fig. 1. It is composed of turns forming two flat spiral coils joined by a solenoid with a gap along its middle section. The construction principle of the flat coils is clear from the figure: concentric left half-turns are coupled along the AA'-axis with turns of the right half plane.

The betatron field is chaacterized by the following parameters: the relationship between curretn I (A) in the winding of the electromagnet and the magnetic guide field H (V) along the equilibrium orbit of radius R_0 (cm) is determined by the relationship:

$$H = \frac{3.9 I}{R_o}$$

Azimuth non-uniformity does not exceed 0.5%. The distribution of the field collapse indicator $n(r,z)$ is represented in Fig. 2.

On the basis of this geometric simulation construction method, a few working accelerators were created with R_0 from 3.9 to 23.4 cm.

In the pulsed operating mode capacitive accumulators are used to power the electromagnet. Energy capacity of the accumulator is determined by the type of betatron used and the final acceleration energy:

$$W = 3.5 R_o E^2$$

for $E \gg m_o c^2$, where W = energy capacity of the capacitive accumulator, J; E = final acceleration energy in MeV.

Characteristic acceleration time is from a few microseconds to a millisecond. Maximal accelerating energy attained in air-cored betatrons using capacitive accumulators is 100 MeV.

Experiments were also performed on powering air-cored betatrons with explosion magnetic generators MK [2].

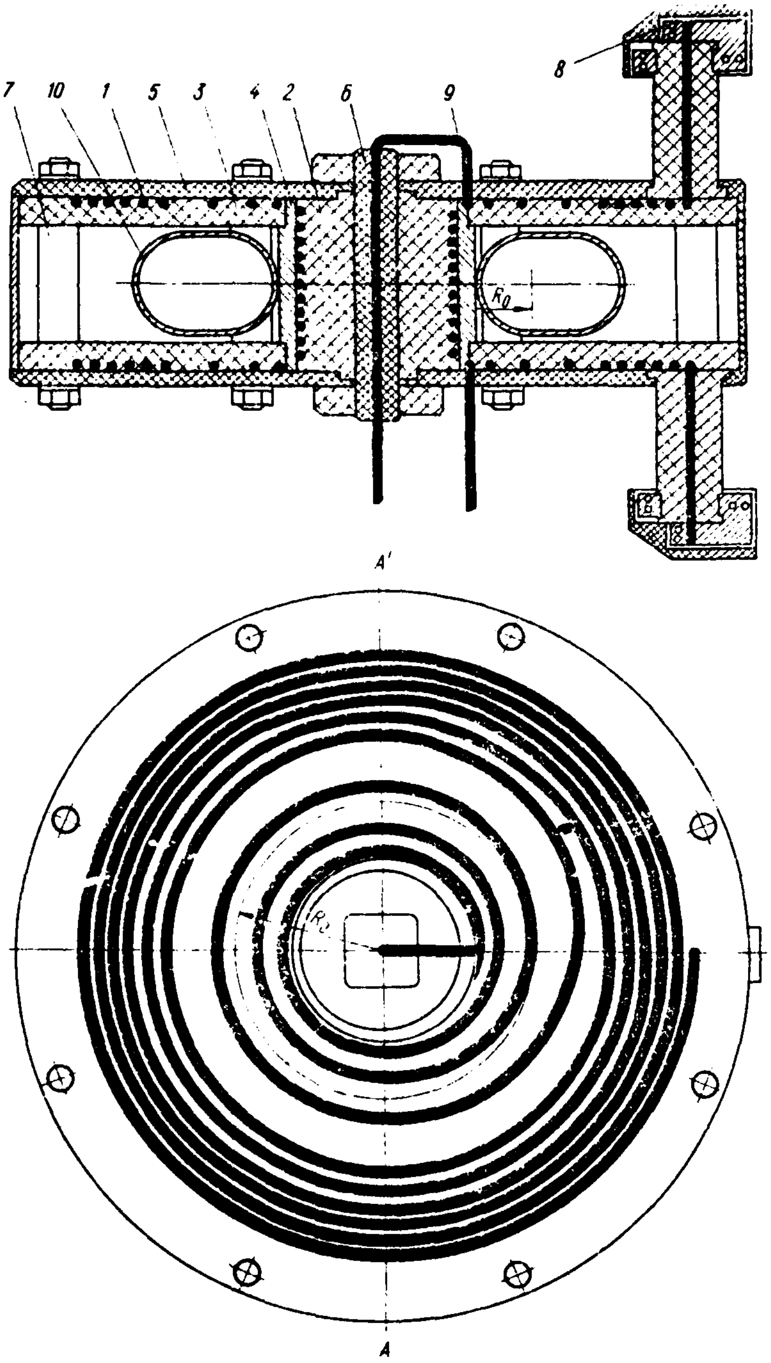

Fig. 1. Construction of air-core betatron.

1 - Electromagnet turns; 2 - Case of the central solenoid; 3 - Case of the flat coils; 4 - Case of central solenoid; 5 - Clamping cover; 6 - Central bolt; 7 - Supports; 8 - End contacts of the electromagnet; 9 - Central solenoid contacts; 10 - Vacuum chamber.

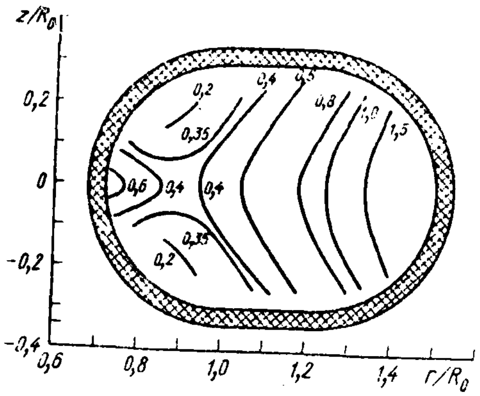

Fig. 2. Distribution of field collapse indicator.

<u>Injection</u>

To attain great circulating currents in air-cored betatrons an external high-voltage injection is applied. The basic type of injector is a sectioned accelerating voltage system of up to 500 kV potential and currents of about 10 A of 10^{-7}-10^{-8} s impulse duration with magnetic beam focusing at the injector output.

To introduce the beam into the stability area, a non-inflector system has been developed to shield the electron channel at the moment of injection with the use of a channel of highly conductive metal causing a low rate of the field's diffusion through the channel wall. To localize the distortions of the magnetic field outside the acceleration area, the input system is equipped with a special shield whose form is determined by the curvature of the magnetic lines of force of the betatron field at the point of its installation.

A characteristic injection feature is operation in the region of the beam's collective interaction: the injection orbit lies outside the stability area ($n \approx 1.5$) and capture is accomplished only with injection currents higher than a certain threshold value. For the convenient operation, vacuum chamber accelerators with $R_0 \lesssim 11.7$ cm are made unsoldered.

Beam discharge at target and output from the betatron chamber

Depending on the output accelerator parameter requirements in betatrons of the type under investigation, different methods are used to displace the electronic beam: by removing the dynamic stability at the end of the acceleration cycle, by orbit deformation, or excitation of forced betatron oscillations.

Basic realized beam displacement methods: unbalancing of currents in the solenoid and the flat "spirals" of the electromagnet when leading current impulse to the points linkup of these elements and excitation of local disturbances of the magnetic field guide with the use of sectorial coils. Indicated discharge systems permit beam discharge to the accelerator target in a time of 10^{-8} to 10^{-5} s, and receipt of bremsstrahlung impulses of corresponding length in this case.

In some cases the accelerated electronic beam was withdrawn from the betatron chamber. Basic withdrawal scheme: overshooting of the electronic beam locally excited in an equilibrium orbit, into a ferromagnetic conical channel followed by its conveyance by a longitudinal magnetic field and compression by a short-focus air-cored magnetic lens. Power supply of conveyance and focusing were combined with power supply of the electromagnet. Output effectiveness in the 5-30 MeV range was 65%. The beam was focused into an area of about 0.5 cm^2.

High current, air-cored betatrons can be used as powerful bremsstrahlung impulse generators for application in industrial flaw detection, in particular of moving objects, in research of fast-flowing processes, and so on.

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